

Puentes, Hermosa, and Torres Reply: In a preceding Comment [1] to our Letter [2] concerning weak measurements with orbital-angular-momentum (OAM) pointer states [2], Pan and Panigrahi show that the real and imaginary parts of higher-order weak values can be made accessible using Gaussian pointer states. In [2], our goal is to show that by using pointer states embedded with OAM it is possible to extract higher-order weak values where pointer states with a Gaussian shape cannot. As a consequence, our work put forward a new tool for weak amplification schemes, i.e., the use of pointer states with more general spatial forms that could be advantageous in some scenarios. We did not intend to claim that a pointer state with orbital angular momentum was needed to extract higher-order weak values in general. We clarify our point with this Reply.

In our Letter we consider a specific Hamiltonian of interaction of the form $H = g_A A P_x + g_B B P_y$, where A , B are operators, (P_x, P_y) are the pointer momentum operators, conjugate to the pointer position operators (X, Y) , and $g_{A,B}$ are coupling constants. Moreover, we calculate the two-dimensional pointer displacement $\langle XY \rangle$, corresponding to a specific measurement. We emphasize that we consider a particular interaction and a specific measurement, which are generally dictated by the physical system under investigation.

The result, Eq. (4) of our Letter, shows that pointer states with OAM ($l = \pm 1$) can be used to retrieve the imaginary part of the higher-order weak values $\langle A^2 \rangle_w$ and $\langle B^2 \rangle_w$, whereas this is not possible with pointer states with no OAM ($l = 0$). In addition, Eq. (9) of our Letter shows, by means of a specific example with $B = 0$, that $\langle XY \rangle = 0$ for Gaussian pointer states. On the contrary, a pointer state with $l = \pm 1$ allows us to extract the imaginary part of the weak value $\langle A^2 \rangle_w$.

Pan and Panigrahi show that by measuring $\langle X^2 \rangle$ one can obtain the real part of the weak value $\langle A^2 \rangle_w$ using a Gaussian pointer [see Eq. (4) of [1]]. However, in order to access its imaginary part, they are forced to use a different interaction Hamiltonian, and a measurement observable involving noncommuting operators. The work of Pan and Panigrahi proves the strength of our proposal: One

need not modify the interaction Hamiltonian by having a different pointer state.

If one is not restricted to the consideration of a particular type of interaction (Hamiltonian) or a specific measurement, one might envision and try to implement different types of interactions and measurements to retrieve the sought-after weak values of interest. However, this is hardly the case in most experimental implementations, the type of interaction and the specific measurement generally being dictated by the experiment itself. In this scenario, the choice is the use of different types of pointer states, which could open a myriad of new possibilities to unveil different weak values. Moreover, pointer states with OAM are readily made in laboratories around the world with present-day technology.

In conclusion, the Comment by Pan and Panigrahi can help to clarify the general meaning and usefulness of the approach considered in our work. Pointer states with OAM are an additional tool which could be used in weak measurement schemes, and which could be convenient in experimental scenarios where the types of interaction and measurement available are given by the physical system under investigation.

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Received 13 May 2013; published 10 July 2013

DOI: [10.1103/PhysRevLett.111.028902](https://doi.org/10.1103/PhysRevLett.111.028902)

PACS numbers: 42.50.Tx, 03.65.Ta, 42.50.Xa

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